Reviews of Biology of Commercially Important Squids in Japanese and Adjacent Waters

I. *Symplectoteuthis oualaniensis* (Lesson)

BY

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(7 Text figures)

Symplectoteuthis oualaniensis[2], an oceanic squid of the family Ommastrephidae, is distributed in the vast warm waters in the Indo-Pacific region, but it has been commercially utilized only in Okinawa (Japan) and Taiwan (Republic of China). This species frequently has been encountered in such large numbers during oceanographic observations along warm water Japanese coasts (ITAKURA, 1977) that a large stock exists for fisheries exploitation. A report of the R/V *Shoyo-Maru* Expedition to the Gulf of Arabia described the existence of a large school of *S. oualaniensis* from the waters off Karachi, Pakistan (document from Far Seas Fisheries Research Laboratory, 1976).

In spite of the economic importance of this squid, very little information on biology and fisheries is available. CLARKE (1966), YOUNG (1975) and WORMUTH (1976) briefly reviewed the biology of this species, while TUNG *et al.* (1973), TUNG (1975, 1976a, 1976b), Ryukyu Fisheries Experimental Station (1971) and Okinawa Prefectural Fisheries Experiment Station (1972) contributed a great deal of fishery-biological information of this interesting squid in the Northwest Pacific. This paper reviews chiefly these recent Chinese and Japanese contributions.

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IDENTITY

Symplectoteuthis oualaniensis (Lesson, 1830) is a species of relatively large animals among the family Ommastrephidae. The largest specimen reported by CLARKE (1966) was 30.5 cm ML (female), but individuals of this species grow much larger. Two females from the Indian Ocean measured 41 cm and 46 cm, respectively (Okutani, unpubl.).

This species is similar to the partly sympatric *Ommastrephes bartrami* (Lesueur, 1821) at a glance, but is easily distinguished from it by its fused mantle-funnel connective (on one or both sides) and an oval patch of photophores on the antero-dorsal surface of the mantle. CLARKE (1965, 1966) noted the existence of a smaller form within the *S. oualaniensis* population that has no photophores. YOUNG (1975) stated that the form with photophores will be considered to be true *S. oualaniensis*, not only for convenience's sake, but also because of its far more frequent occurrence. WORMUTH (1976) took the same view as Young and considered that the 2 forms likely are distinct species.

DISTRIBUTION

Rhynchoteuthion larvae of *Symplectoteuthis oualaniensis* may be contained among those reported as "*S. oualaniensis*-type larvae" by OKUTANI (1964), OKUTANI & McGOWAN (1969), SHOJIMA (1969) and YAMAMOTO & OKUTANI

[1] English version of the proceedings of the symposium on the current status of cephalopod fishery in the waters around Japan, held at Niigata, Japan, 10-11 March 1977

[2] ZUEV *et al.* (1975) incorrectly applied the generic name *Sthenoteuthis*

(1976). The "*S. oualaniensis*-type larvae" are characterized by: (1) a long "proboscis" (fused tentacles), (2) fewer mantle chromatophores than in *Todarodes pacificus* larvae, (3) smaller size in comparison to the equivalent stage of *T. pacificus* (*i. e.*, the tentacles separate at a stage smaller than 7 mm ML), and (4) a pronounced intestinal photophore (CLARKE, 1966; Nesis, personal communication) (Figure 1). A large number of this rhynchoteuthion is distributed in the surface waters around Japan and Taiwan, but separation of true *S. oualaniensis* rhynchoteuthion from larvae of other sympatric ommastrephid species has not always been well established. Rhynchoteuthion larvae of *S. oualaniensis* may occur in summer in more offshore waters where those of *T. pacificus* are seldom distributed then. At a juvenile stage of ML 5 - 6 cm, *S. oualaniensis* is easily distinguished by the very pronounced intestinal photophore and the mantle-funnel fusion (the latter characteristic is not distinct in early larvae the integument of which is still very delicate). Juveniles frequently are aggregated in inshore waters of oceanic islands. According to the observations of one of us (T. O.), such aggregations of juveniles were found at Hachijo Island and Ogasawara (Bonin) Islands. Juveniles dip-netted near the Seychelles in the Indian Ocean (OKUTANI, 1970) and from Guadalupe Island, Mexico (Invertebrate Collection in the Scripps Institution of Oceanography) were also examined. YOUNG (1975) also recognized the abundance of juveniles in some insular areas by the evidence from birds' stomach contents. On the basis of an observation on behavior of a dip-netted juvenile that adhered to the bottom of a container, Okinawa PFES (1972) assumed that the animal may crawl on the bottom in its natural environment. It is difficult to believe that this assumption was correct, as such behavior was most unlikely a normal posture.

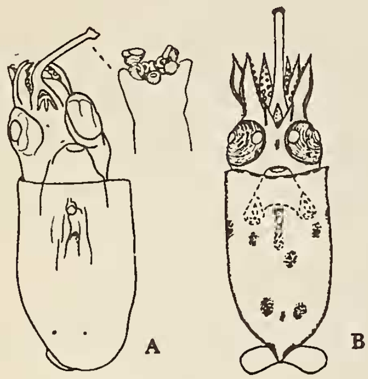

Figure 1

Rhynchoteuthion of *Symplectoteuthis oualaniensis*

A: After CLARKE (1966) B: After NESIS (unpublished)

Symplectoteuthis oualaniensis is known to be abundantly distributed in the surface waters both day and night, as it frequently is jigged or dip-netted at the surface and also is seen "flying" over the sea surface (ITAKURA, 1977). No direct evidence on vertical distribution of this species has been available. YOUNG (1975) inferred that this species may have a vertical distribution similar to that of the related genus, *Ommastrephes*, that is known to occur from the surface to depths of 1500 m.

The major fishing grounds are located on the southwestern coasts of Taiwan (TUNG, 1976a) and beyond the 200 m-contour off the Ryukyu chain (Ryukyu FES, 1971) (Figure 2). The fishing season near Taiwan is from March to November with the peak in May - August. Fishing is most productive at water temperatures above 26° C and particularly around 28° C. In the Ryukyu waters, the fishing season lasts from May to October at Yaeyama Region and from June to November at Okinawa Region. The surface water temperature for the season varies from 22° C to 28° C. The coastward shift of the 27° C-isotherm corresponds well to the location of the fishing grounds (Ryukyu FES, 1971). The landings of *Symplectoteuthis oualaniensis* at 2 major fishing ports in Taiwan and one in Okinawa are shown in Table 1. At 29° N, 135° E, this squid is continuously seen from May to October, particularly frequent at above 23° C in surface temperature at the station (ITAKURA, 1977).

Table 1

Landing of *Symplectoteuthis oualaniensis* in Taiwan (Kaohsiung and Henchun) and in Okinawa (Itoman) (TUNG *et al.* 1973; Ryuku Fisheries Experimental Station 1971). Unit: Kg

	Taiwan		Okinawa
Year	Kaohsiung	Hengchun	Itoman
1966	[4]	[4]	42014
1967	[4]	[4]	47659
1968	[4]	[4]	41501
1969	[4]	[4]	29907
1970	149556	6414	49166
1971	106566	3837	[4]
1972	28219	1181	[4]

[4]No published data are available.

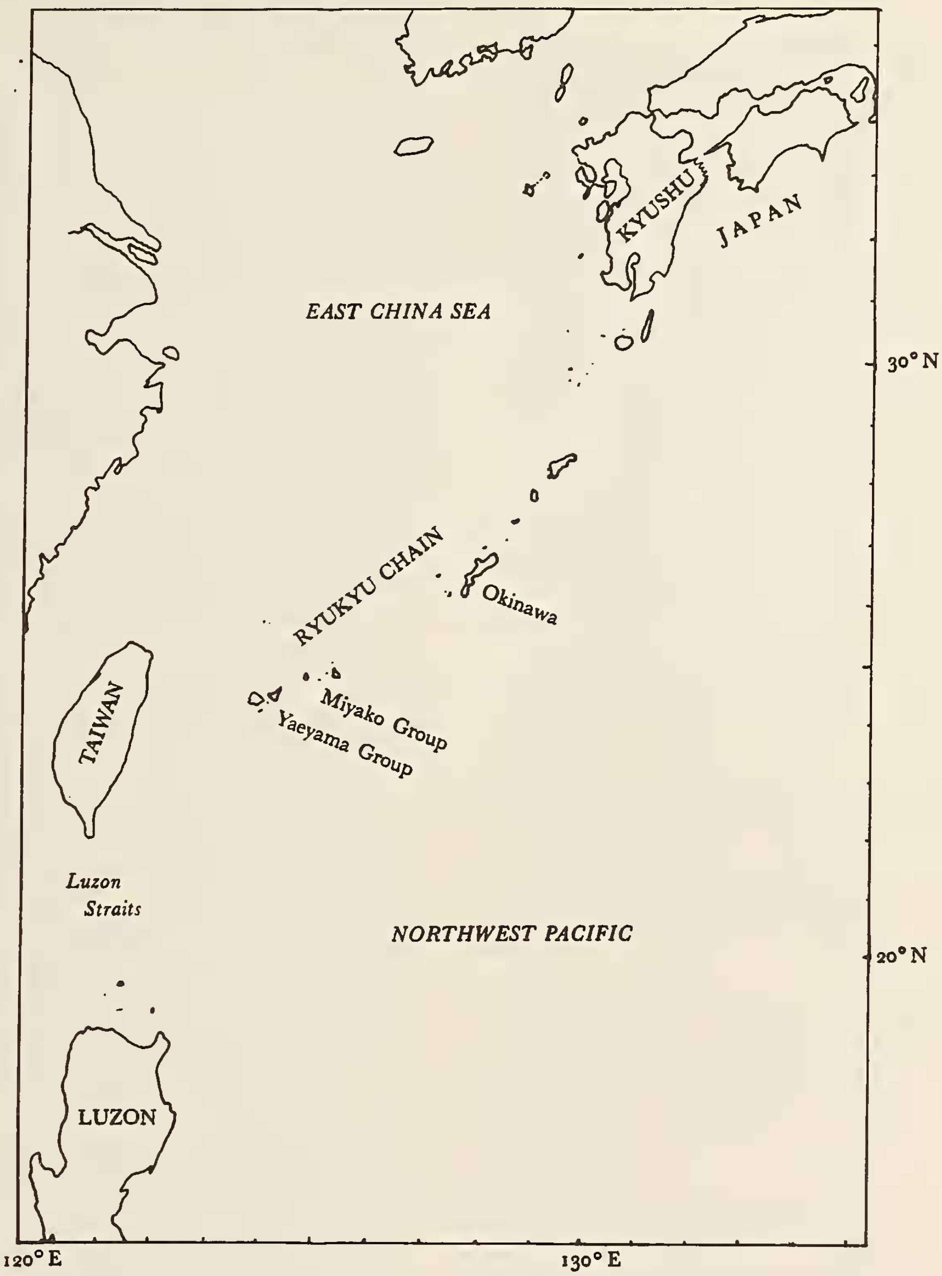

Figure 2

Index Map for Okinawa – Taiwan Area

GROWTH

TUNG *et al.* (1973) recognized 2 size groups[3] in May: 12 - 18 cm ML and 19 - 24 cm ML. The smaller group grew to 16 - 22 cm in mid- to late June, while the larger group vanished from the fishing ground. Simultaneously another school with a mode at 12 - 13 cm ML entered the area and similar small-sized groups are recruited continuously until early September. Recruits grew as big as 16 to 17 cm by November (Figure 3). Therefore, the squid grows 4 cm in 2 months (from early May till early July and from early September till early November). Such a recruitment of smaller size groups has also been apparent in the sea around Okinawa (Ryukyu FES 1971 and Okinawa PFES 1972). The relation between ML and body weight (BW) given by TUNG *et al.* (1973) is:

$$\log BW = 2.8481 \log ML - 4.0088.$$

According to the most recent study by NESIS (1977), the population of *Symplectoteuthis oualaniensis* in the western tropical Pacific is composed of 2 different groups, namely, a small and early-maturing group (EM) and a large and late-maturing group (LM). The EM matures at 10 cm ML in males and 13 cm ML in females with a life span of about 8 - 9 months, while the LM matures at 12 - 13 cm ML in males and 20 - 24 cm ML in females with a life span slightly longer than one year. The EM is distributed only in the central part (between 55° E and 175° W, and 10° - 15° N and S) of the whole range of the species. The EM differs from the LM in the absence of the dorsal photophore patch, which is differentiated in the LM at about 10 cm ML. Nesis also mentions that spermatophore and heterocotylus are different from each other. This supports the view of CLARKE (1966) and WORMUTH (1976) that 2 forms within *S. oualaniensis* are different from each other not only in the presence (and absence) of the dorsal light organ but also in size at maturity, maximum size, abundance and distributional range. Nesis thinks that these groups are genetically differentiated "superpopulations" within the species.

REPRODUCTION

The left arm IV is hectocotylized and is developed from about 11 cm ML onward. Unlike that in *Todarodes pacificus,* in which the distal half of the right arm IV is modified into comb-like papillae mostly with suckers, the distal half (50.3 ± 2.66%) of the hectocotylized arm completely lacks suckers and has a sharp fleshy ridge with smooth or undulated sides. The hectocotylized arm is slightly longer (114.9 ± 5.8%) than the normal right arm IV.

[3] On photophore-bearing type only

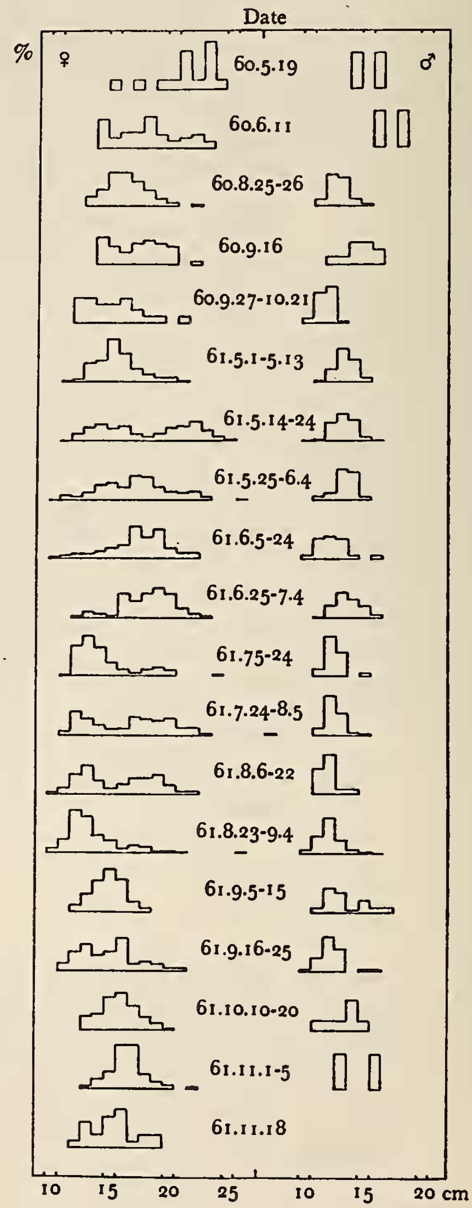

Figure 3

Seasonal Change of Mantle Length Composition (TUNG *et al.*, 1973)
The years 60 and 61 correspond to 1971 and 1972 A. D.

Concerning the sex ratio of this squid, Tung *et al.* (1973) and Tung (1976a) found that the males comprise about 31% of the population in the early fishing season and 21% in the closing season (average 25%). The sex ratio is 1 : 1 at the stage of 10 - 13 cm ML, while males gradually diminish in numbers after 14 cm ML. Females strongly predominate in the commercial catches in Okinawa, comprising some 70 - 80% thereof (Okinawa PFES, 1972). This may coincide with the fact that males mature much earlier than females and disappear from the fishing grounds. Also, schools appear first in the north of Luzon with a high ratio of males and migrate northward along the Kuroshio Current, spreading to the southwest and east of Taiwan and then northward to the Ryukyu Region.

Tung (1976a) observed copulating behavior at 0300 on June 28, 1973, at surface at 21°06'N; 120°58'E, north of Luzon. The observed pair was a male about 13 cm and a female about 20 cm. The female which had been swimming about 20 cm ahead of the male suddenly changed its orientation and grasped the male in a head-to-head position. The male then changed its position to form an angle of 45° with the female, but soon returned to the linear head-to-head position while sinking out of sight.

Among 37 males captured at that time, 35 carried spermatophores and among 136 females, 72 were impregnated with spermbulbs. This species does not seem to eject all spermbulbs at one copulation but may copulate with several females. Artificial fertilization experiments were made on board the ship at the same time. Among 3 trials, the most successful one had a fertilized egg develop until blastopore formation and differentiation of the eyes.

The asymmetrical ripe eggs are translocated to the oviduct when the ova are 0.75 mm in major diameter. The number of ova rapidly increases since at 15 cm ML, 5 g of ovary contain 10 000 to 20 000 eggs. The relation between ovary weight (W_{ov}) and ML is:

$$W_{ov} = 4.18\ ML - 65.34$$

The largest ovary ever measured was 58.4 g and contained 250 000 eggs.

Eggs in the oviduct measure 0.788 ± 0.03 mm (0.714 - 0.872 mm) in major diameter. The minor diameter is about 84.54 ± 1.95% (80.03 - 87.86%) of the major diameter. The maximum weight of the oviduct is about 40% of the entire female reproductive system. The eggs in the oviduct attained a maximum weight of 33.1 g, in which there were 123 562 eggs present.

Nidamental glands are as small as 2 cm in squid of 15 - 16 cm ML but grow to 7 cm at 18 - 19 cm ML. The relation between the length of the nidamental gland (Ln) and mantle length shows a logarithmic curve in which the point of inflexion is present at 17.2 cm ML or 4.7 cm in Ln (Figure 4). The relation between weight (Wn) and length of the nidamental gland is:

$$Wn = 0.070924\ Ln^{2.335254}.$$

The relations among various measurements in the male reproductive system and ML are shown in Table 2 (Tung, 1976a).

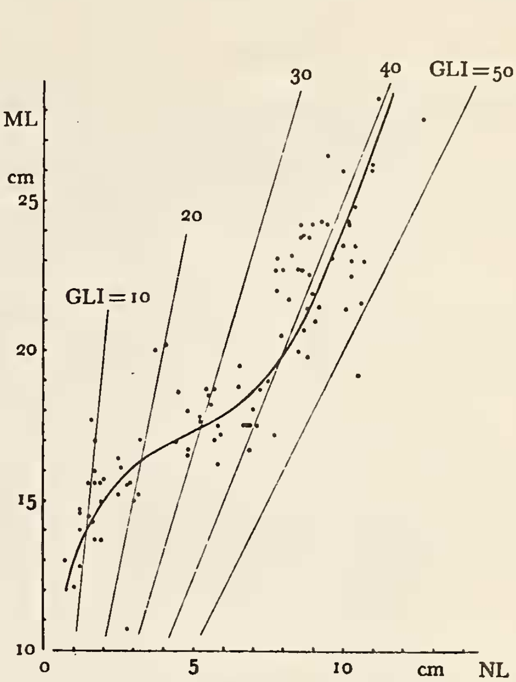

Figure 4

GLI = (Ln/ML × 10² (Tung, 1976a)

The spermbulbs are implanted around the female's mouth. Close examination of 10 females showed 15.2 spermbulbs implanted on the ventral side of the inner lip of the buccal mass, 6.1 on the dorsal side, 0.2 on the outer lip, 0.3 on the inner surface of the buccal membrane, 1.4 in the outer region of the same, and 0.6 on other places, such as the base of the arms. The spermbulbs planted usually are covered by a gelatinous covering and are embedded in the soft tissues of the lips for $\frac{1}{3}$ - $\frac{2}{3}$ of the length of the bulbs. All of the females larger than 24 cm ML are implanted with spermbulbs, ranging from 1 to 83 bulbs (Figure 5). The seminal receptacle usually is composed of 2 vesicles, but occasionally of 5 - 6. They are unevenly distributed around the buccal membrane and vary from 9 to 163 in number. The seminal receptacles are usually undeveloped in females smaller than 13 cm ML. The ratio of specimens having receptacles exceeds 50% at 15 cm ML and reaches 100% at 18 cm ML.

Table 2

Relation between measurements in male genital organ and ML (TUNG 1976 a).

Entry	Corr. Coef.	Regression formulae
Testis weight – ML	0.865**	$W_t = 0.0364ML - 2.836$
Seminal duct w. – ML	0.792**	$W_{vd} = 0.0673ML - 6.519$
Seminal duct w. – Testis w.	0.798**	$W_{vd} = 1.542W_t - 0.666$
Seminal duct l. – ML	0.357**	$L_{vd} = 0.3612ML + 15.881$
No. of spermatophore – ML	0.497**	$N_{sp} = 0.9846ML - 99.38$
No. of spermatophore – Testis w.	0.255*	$N_{sp} = 11.680W_t + 7.993$
No. of spermatophore – Seminal duct w.	0.718**	$N_{sp} = 17.085W_{vd} - 9.185$
Spermatophore l. – ML	0.703**	$L_{sp} = 0.1349ML + 0.503$

*Significant level at 5%, ** at 1%, respectively.

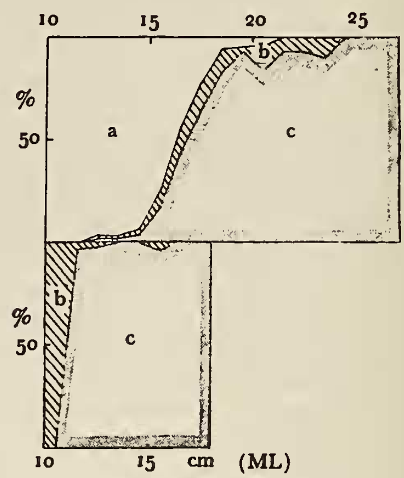

Figure 6

Ratio of Three Grades of Maturity by ML Classes (TUNG, 1976a)
Female (upper panel), a: immature ($W_{ov} < 3$ g), b: mature ($W_{ov} > 3$ g), c: fully mature (ova present in oviduct)
Male (lower panel), b: mature (Wt. 2 g), c: fully mature (spermatophores present)

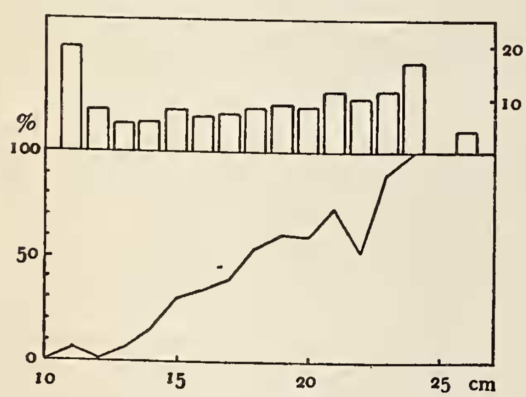

Figure 5

Ratio of Impregnation of Sperm Bulbs on Females (lower panel) and Average Number of Sperm Bulbs (upper panel) by Mantle Length (TUNG, 1976a)

TUNG (1976a) defined 3 stages of maturity: "immature" for less than Ln = 2.5 cm or 15.5 cm ML, and "fully mature" for Ln over 7.5 cm or ML over 19 cm. The stage between these two may be "mature." Among "immature" specimens, Wn 1 g are allocated as "mature," and those in which GW/BW exceeds 10% are allocated as "fully mature" (Figure 6) (GW = gonad weight; BW = body weight).

At the time of the first appearance of the squid schools in the southwestern waters off Taiwan, most of the females are immature. They gradually become mature and spawn in June. Along with the disappearance of the large-sized squid, another population of small squid appears in July-August and they become fully mature in September-October. The third population that appears in November seems to mature in February-March of the next year. Therefore, the successive appearance of immature squids that mature several months apart well corresponds to the size composition. In conclusion, the *Symplectoteuthis oualaniensis* population in Taiwanese waters is composed of 3 different (seasonal) subpopulations.

Among the population that appears in the north of Luzon, some fully mature females are found. The schools that appear in the southwestern waters off Taiwan in June are composed of squids of advanced maturity. This school may spread in a clockwise direction but partially migrate up north to the Miyako Islands via the East of Taiwan. The mature individuals move ahead of the less mature squids. Spawning of these squids in the South China Sea is corroborated by SHOJIMA (1970) who reported rhynchoteuthion larvae which probably belong to this species, of 0.6 - 6.4 mm in summer. Rhynchoteuthions of *Todarodes pacificus* never occur there in that season.

FOOD

TUNG *et al.* (1973) and TUNG (1976b) found the maximum content of a stomach to be 52.6 g (at 27 cm ML), but the contents usually weigh 1 - 3 g. Empty (less than 0.5% of body weight), medium (less than 3%) and full (over 3%) stomachs occupy 62%, 33% and 4%, respectively, of examined stomachs. The relation between ML and weight of a full stomach (Ws) is:

$$\log Ws = 3.4576 \log ML - 6.751$$

According to this, the average full stomach contents of the squid between 10 and 25 cm ML is 3.24 to 5.25 (Figure 7).

The stomach contents are composed of pieces of squid flesh, horny rings, hooks, squid eyeballs, jaw plates, fragments of gladii, scales of fishes (probably 4 - 5 cm in body length), vertebrae, fish eyeballs, crustacean remains, spermbulbs and parasites. The squids that preyed mainly on fish accounted for 36.7% (among them $\frac{2}{3}$ preyed entirely on fish), on crustaceans - 20.5%, on squids - 18.4%

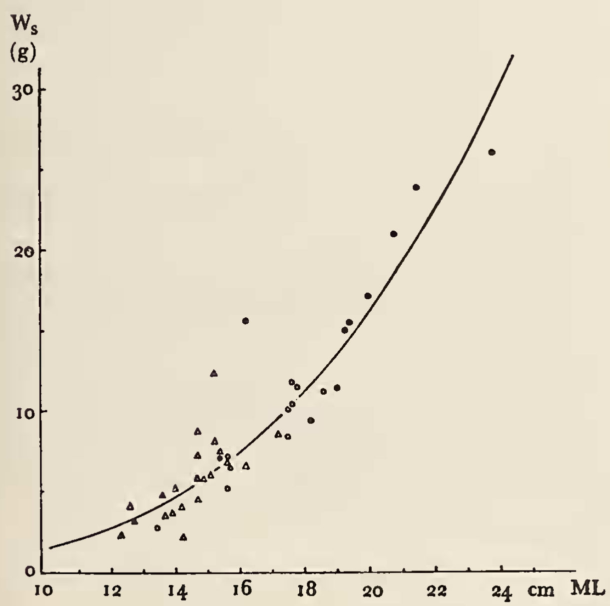

Figure 7

Relation between Content Weight of full Stomach (W_s) and Mantle Length (TUNG, 1976b). Dots: fully mature; circles: mature; triangles: immature specimens

and on unidentified substances - 9.8% of examined squid specimens.

A regional tendency exists in prey-species composition: squid captured in the southwest of Taiwan contained mostly fish, in the east of Taiwan, a mixture of fish and squid, and around Okinawa more frequently crustaceans. Seasonal differences may be within the range of areal variation.

The stomach content index (= SW/BW × 100) is higher in the early half of night (maximum 1.43) and lowers towards dawn. The relation between maturity and food intake is not clear, but the larger the squid grows, the smaller the index becomes.

YOUNG (1975) stated that *Symplectoteuthis oualaniensis* mainly preys upon fish. He reports that a single stomach contained remnants of 14 fishes. Other prey were enoploteuthid squids and various crustaceans, but the latter were thought to be from the ingested fish stomachs. WORMUTH (1976) listed 15 fish species that were identified from otoliths: *Stolephorus purpureus, Exocoetus volitans, Oxyporhamphus micropterus, Ceratoscopelus, Centrobrunchus, Vincigueria,* 2 species each of *Hygophum, Diaphus,* and *Myctophum,* and species of Centrolophidae, Gempylidae and Holocentridae, all in Hawaiian waters. Besides squid beaks, he identified *Hyaloteuthis pelagica, Onychoteuthis banksii* and an enoploteuthid squid in the diet of *S. oualaniensis.* His description on a way of preying upon myctophids based on his observations on board ship is quite similar to what we have observed.

PREDATORS

No report has been available on predators of this squid in the Northwest Pacific, except a finding of *Symplectoteuthis oualaniensis* in the stomach content vomited by an unidentified sea bird (T. O.).

CLARKE (1966), YOUNG (1975), and WORMUTH (1976) listed as predators of *Symplectoteuthis* the sea birds: *Phaeton rubricauda, Puffinus nativitatis, Pterodroma alba, Sterna fuscata, Anous stolidus, A. tenuirostris, A. minutus, Gygris alba, Porcelsterna caerulea, Sula piscator, S. sula* and *S.* sp. As fish predators, *Coryhaena hippurus, Gemphylus aerpens* and several tuna are listed by WORMUTH (*op. cit.*).

PARASITES

TUNG (1976a) found that 13.2% of females and 6.0% of males examined were infested by parasites, of which 92.6% were trematodes 0.6 - 6.0 mm long. The rate of infestation is higher in the population in the southwest-south of Taiwan, lower in the east of Taiwan, and lowest in Okinawan waters. In general, the larger the squid, the higher the rate of infestation: 7.0% for immature, 15.5% for mature, and 34.8% for fully mature (average 13.2%).

FISHING

Symplectoteuthis oualaniensis has been commercially utilized only in Taiwan and Okinawa. The traditional fishing boat in Okinawa is a small row-boat of less than 1 ton. The annual squid and cuttlefish landings during 1947 to 1969 was 325 tons, and 70% was *S. oualaniensis* (Ryukyu FES, 1971). Motor-driven squid jigging machines have been used experimentally and the results revealed that the machines catch slightly smaller squids (Ryukyu FES, 1971).

Symplectoteuthis oualaniensis is a byproduct in the Taiwanese fishery. Tung *et al.* (1973) found that *S. oualaniensis* seldom stayed near the boat during experimental use of motor-driven jigging machines, even if they showed positive phototaxis to the fishing lights. The squid in the shadow of the boat are more easily attracted by jigs operated by machine, but those that stay in dim light at 15 - 25 m depth are more accessible to hand lines. Poor catches are obtained during full moon.

Another technical problem is that the arms of *Symplectoteuthis oualaniensis* are easily broken by motor-driven jiggers(originally designed for *Todarodes pacificus*); *e. g.*, while 499 squids were captured, 365 broken arms (without whole animal) were hooked. This means almost half of the hooked squids were not taken aboard.

The size of squid caught in Taiwan and Okinawa is good for bait for the tuna long line fishery. *Symplectoteuthis oualaniensis* also is good for human consumption and is being used on a small scale. However, attracting and keeping the schools under the fishing light for long duration and preventing broken arms are technical problems to be overcome.

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